DTE Energy
Detroit Edison

Power Factor Improvement

State Energy Assessment Workshop

By:

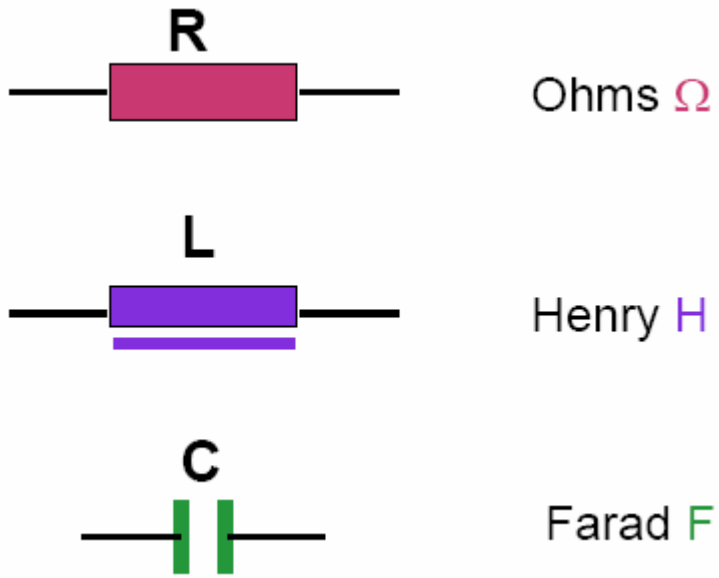
DTE Energy Partnership & Services

Power Factor (pf) Correction

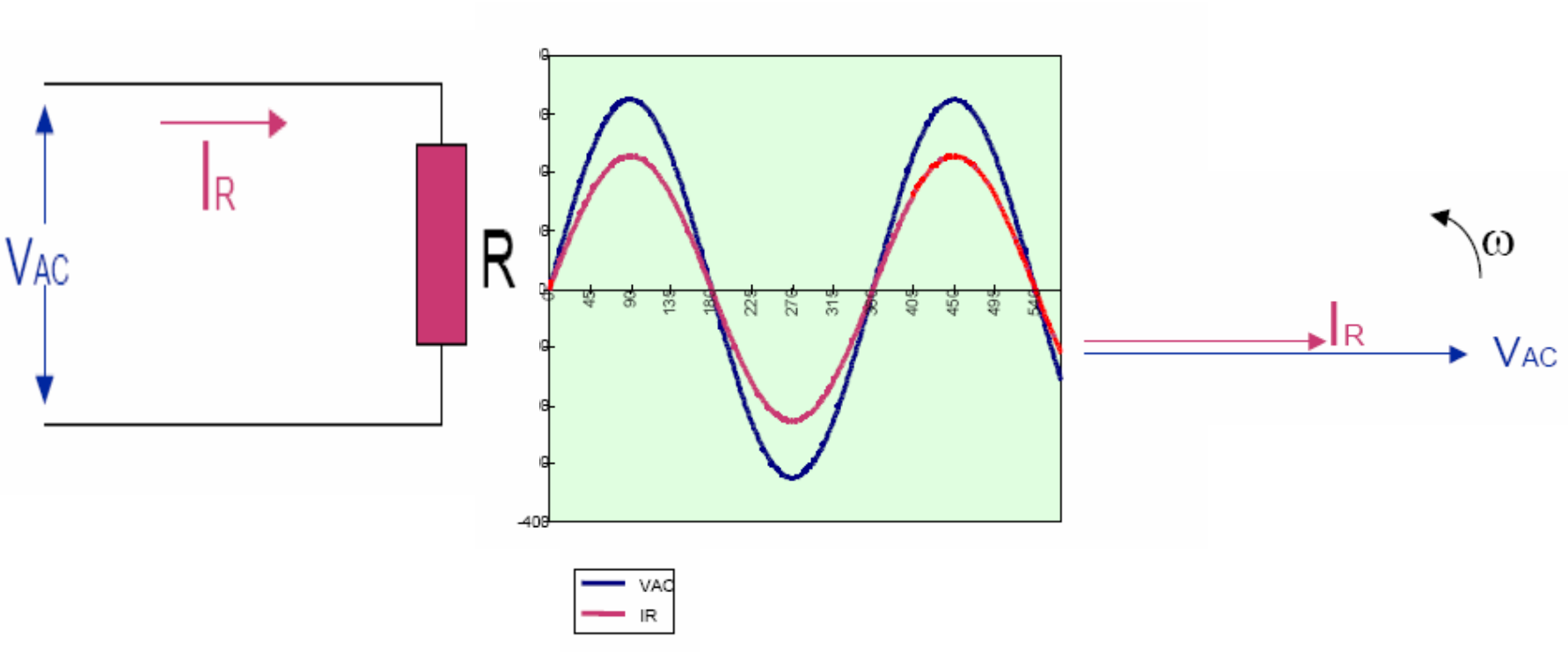
- Why is it needed
- How do we correct it
- How does it affect electrical bills

Types of loads

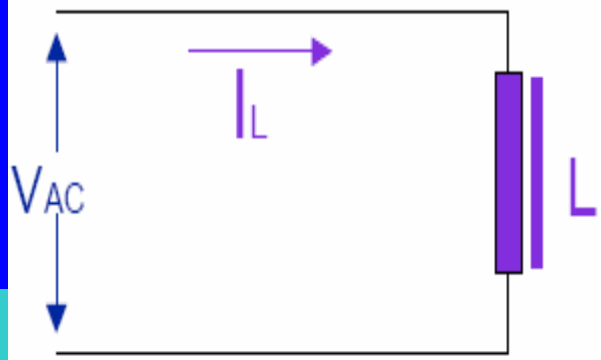
- There are three categories
  - Resistive
  - Inductive
  - Capacitive

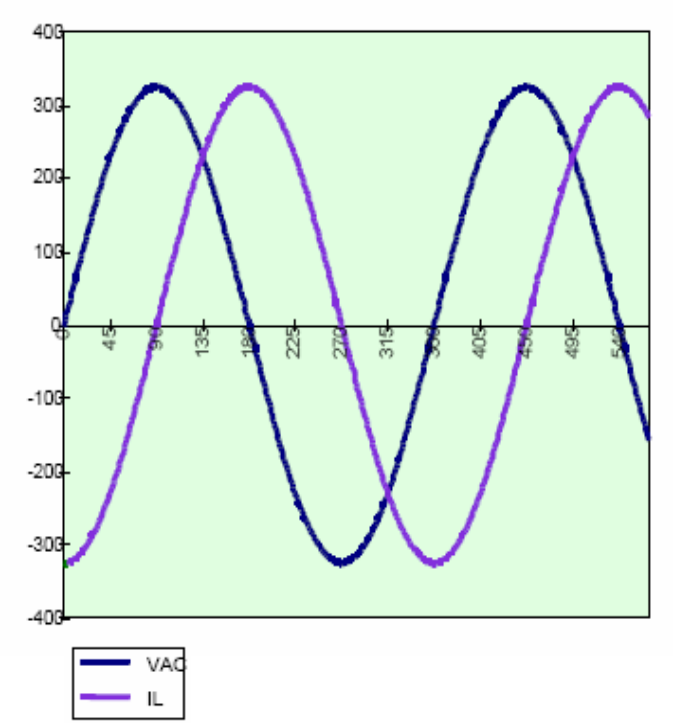


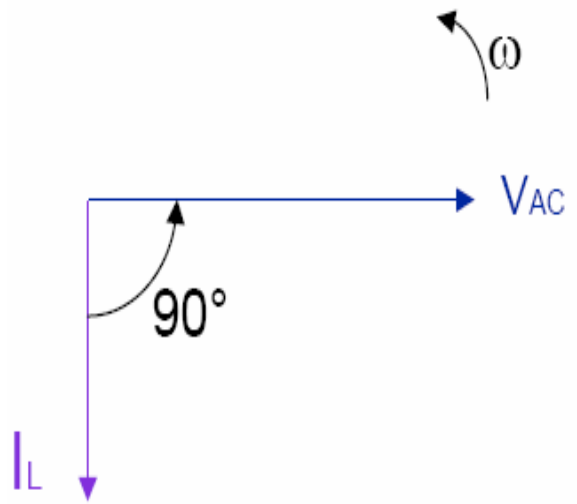
Resistive Load



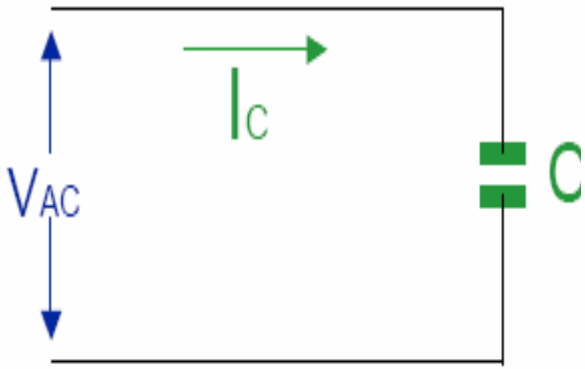
Inductive Load

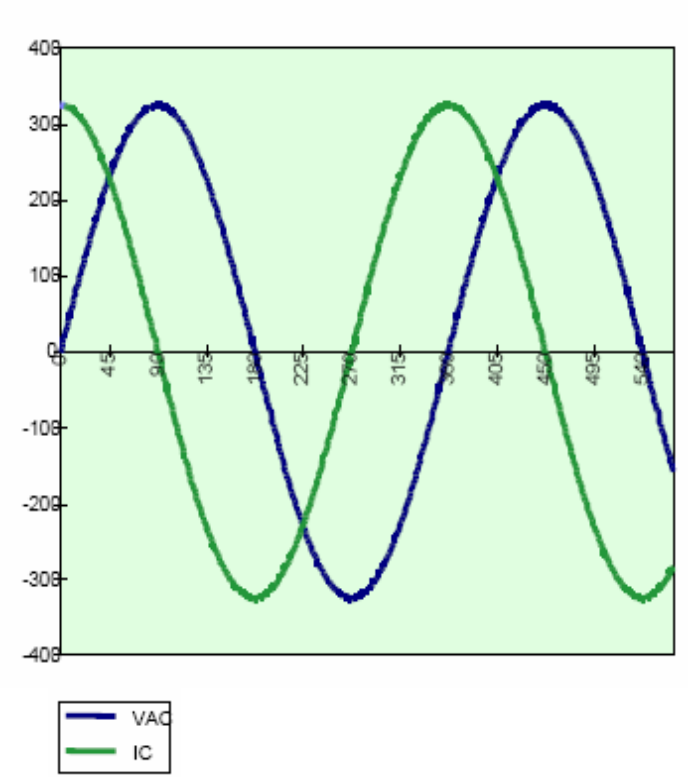


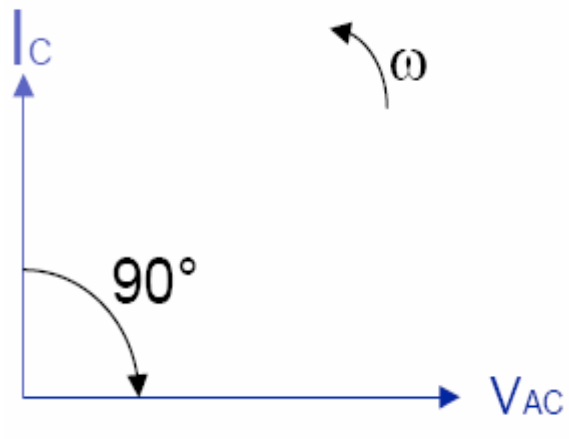




Capacitive Load





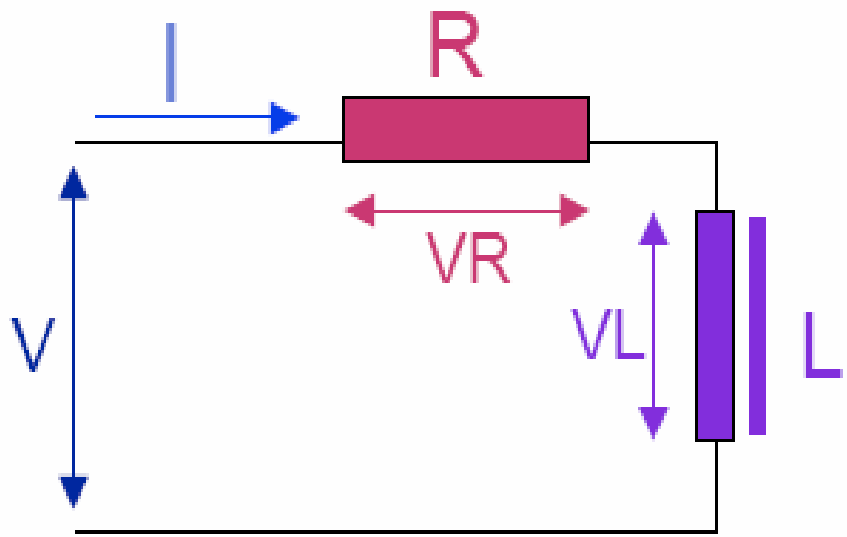


Power

- Real Power (P)
  - Is the actual amount of power being used or dissipated in a circuit; measured in watts.
  - It is a function of a circuits resistances R; $P = I^2R$
- Reactive Power (Q)
  - Is the amount of absorbed/returned power by the reactive loads (KVAR)
  - It is a function of a circuit's reactance X; $Q = I^2X$
- Apparent Power
  - Is the combination of reactive power and true power; measured in (VA).
  - It is a function of a circuit's impedance Z; $S = I^2Z$

Real Loads

- Main industrial loads can all be considered to be a combination between resistive and inductive loads
- Current always lags Voltage by some angle except in total resistive loads



Power Factor

- Is a measure of how effectively the current is being converted into useful work output
- Is a good indicator of the effect of the load current on the efficiency of the supply system.

Power Factor

KVAR
Reactive
Power

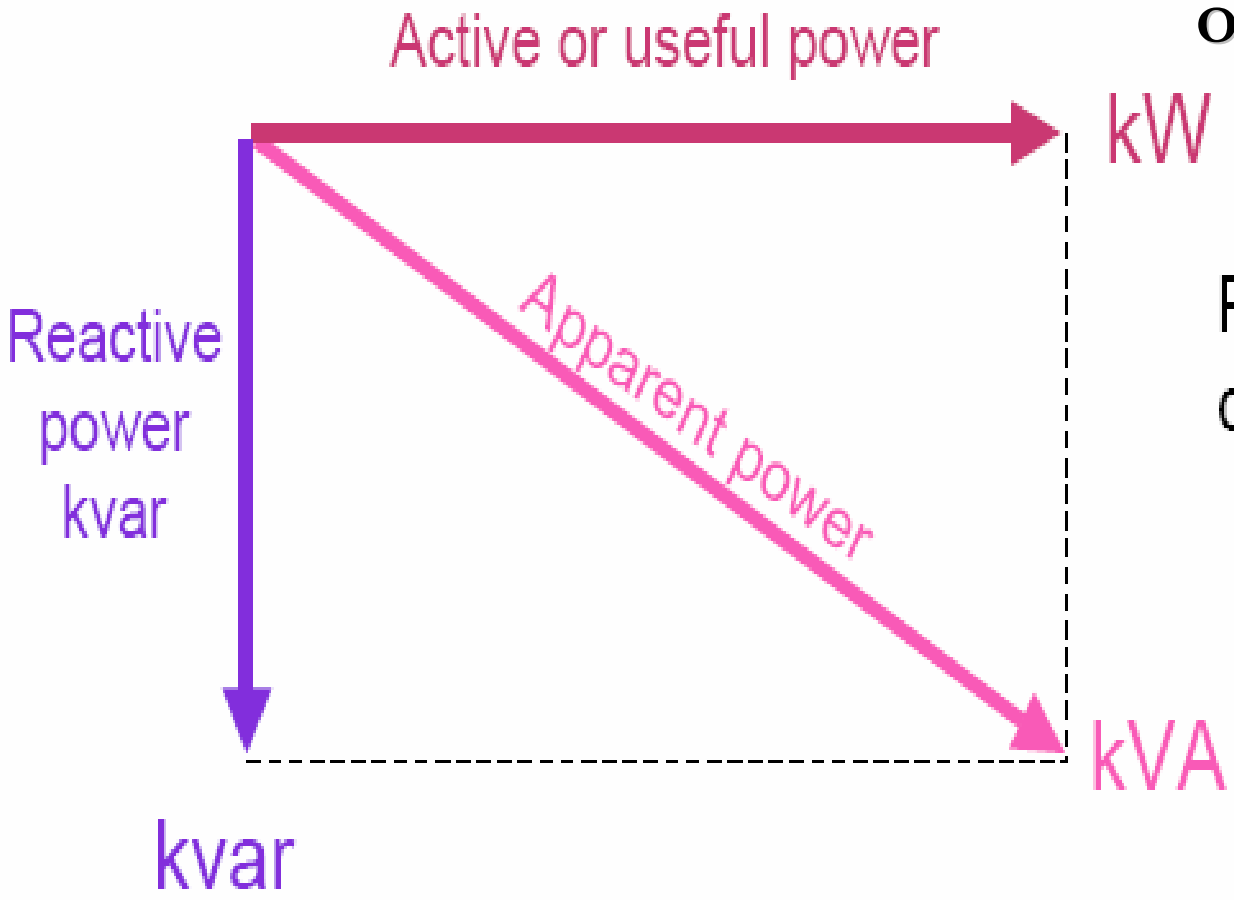
kW
Active
Power

kVA
Apparent
Power

$$PF = \frac{kW}{kVA}$$

Power:

Power Factor is a measure of Efficient Output/Input



Power factor

$\cos \phi = kW / kVA$

Basic Concepts

$$\cos \Phi = \frac{kW}{kVA}$$

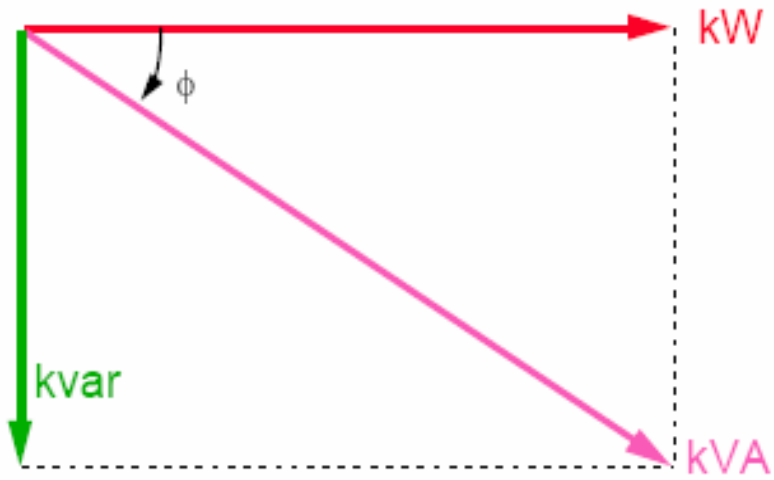
$$\sin \Phi = \frac{kvar}{kVA}$$

$$kVA = \sqrt{kW^2 + kvar^2}$$

$$\cos \Phi = \frac{kW}{\sqrt{kW^2 + kvar^2}}$$

$$\tan \Phi = \frac{kvar}{kW}$$

$$kvarc = kW(\tan \Phi 1 - \tan \Phi 2)$$

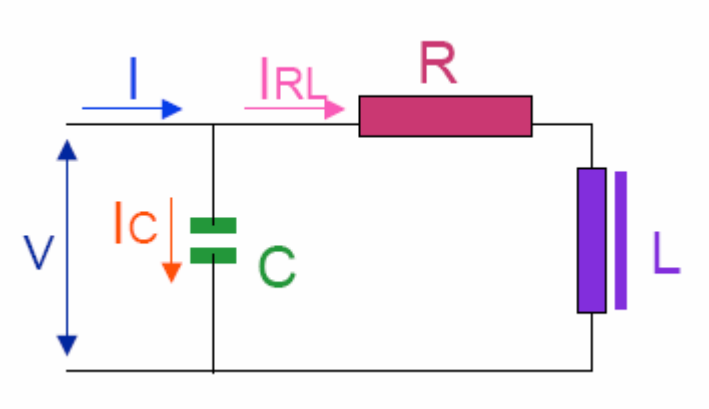


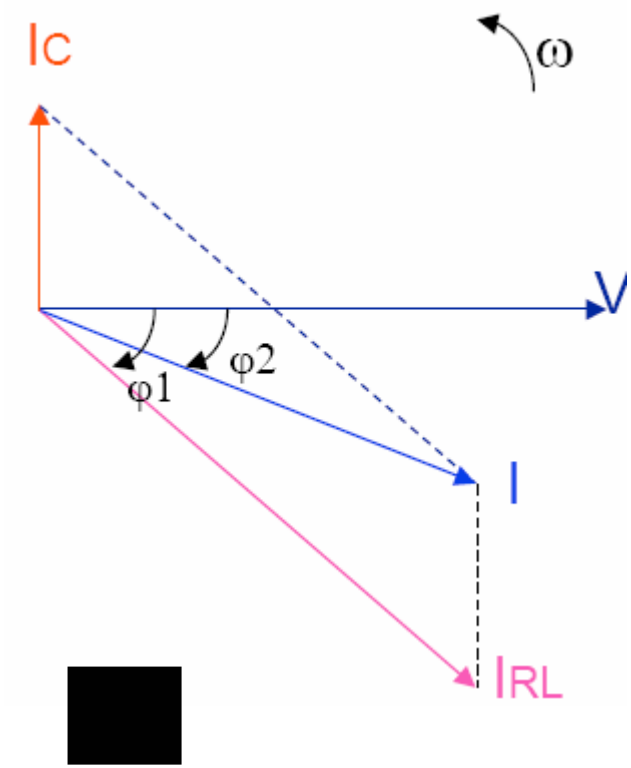
How to Improve Power Factor

- Using the correct sized motor for a particular job
- Shutting off unused motors
- Installing a capacitor.

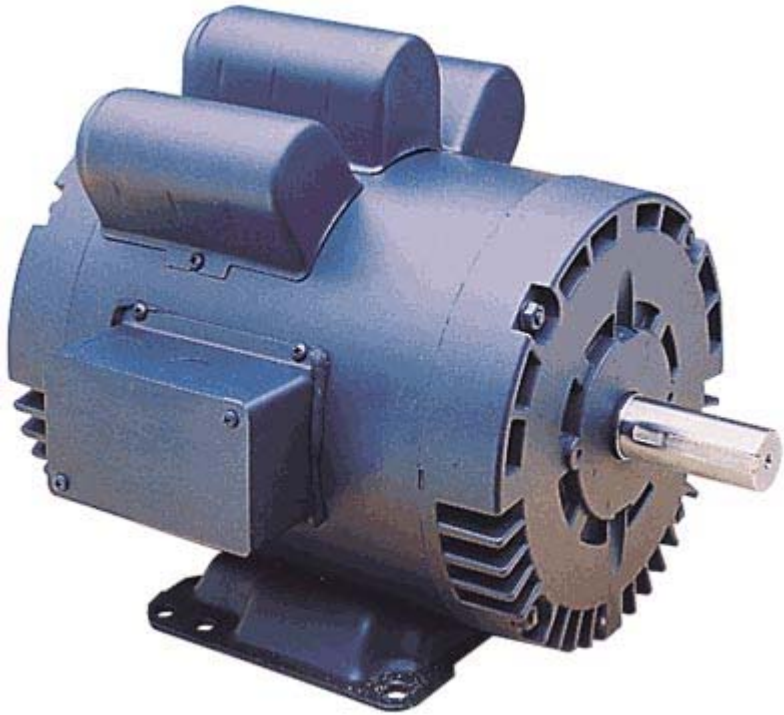
Adding a Capacitor

- Capacitor connection

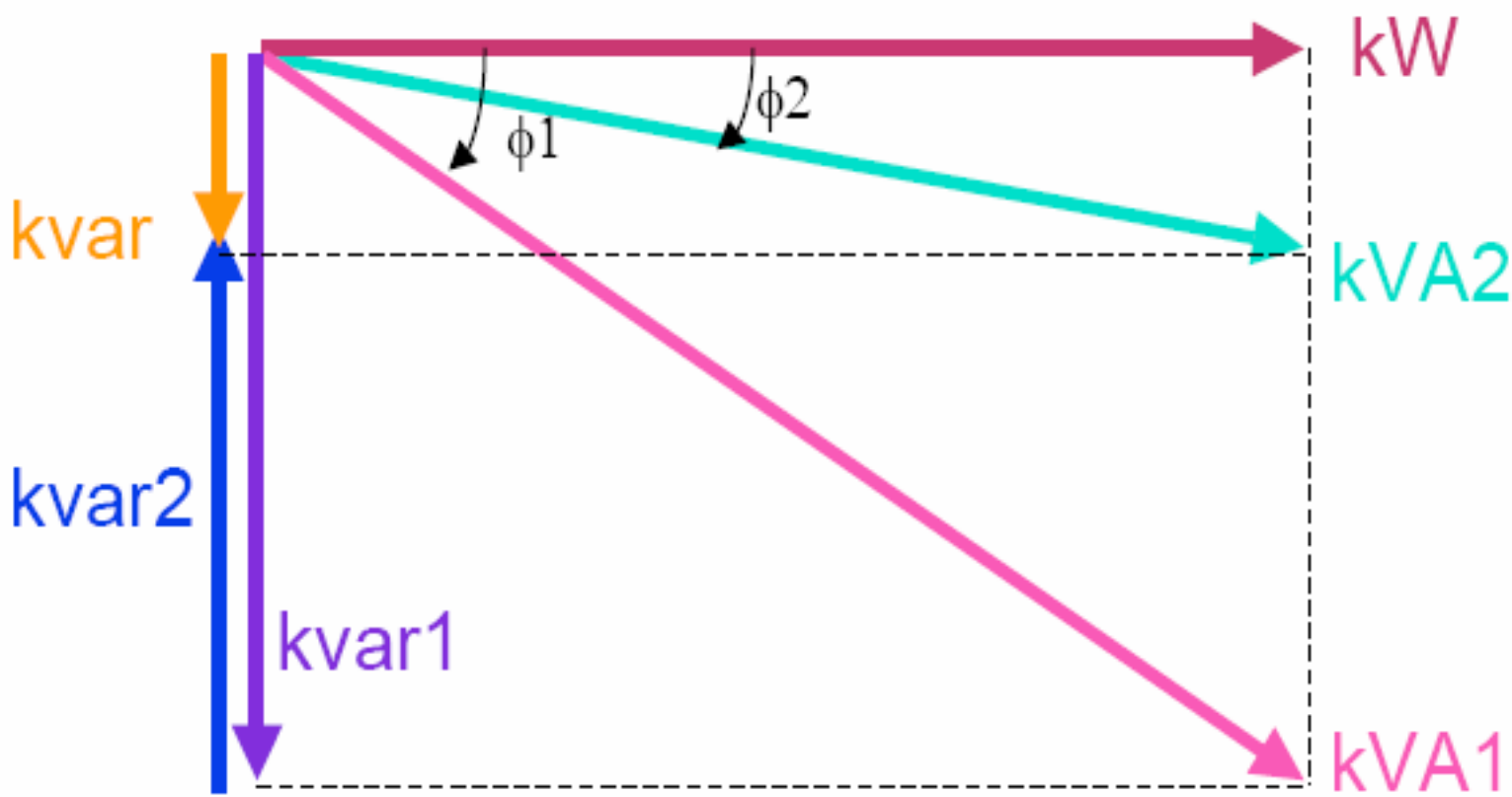




As φ ↓, Cos φ ↑, and I ↑

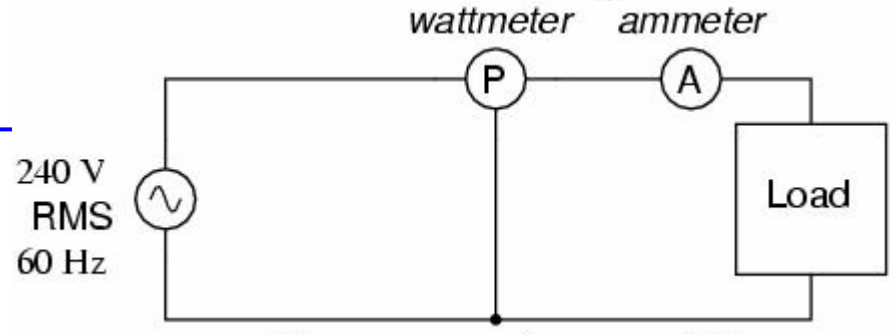


Adding a Capacitor



Example

Find pf and capacitor value to correct the pf.

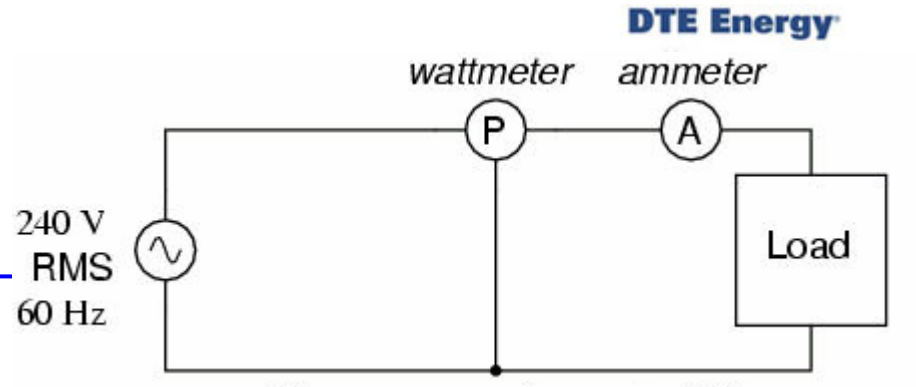


Wattmeter reading = 1.5 kW

Ammeter reading = 9.615 A rms

$$S = IE = (9.615A)(240V) = 2.308\ kVA$$

$$\text{pf} = \frac{P}{S} = \frac{1.5kW}{2.308kVA} = 0.65$$

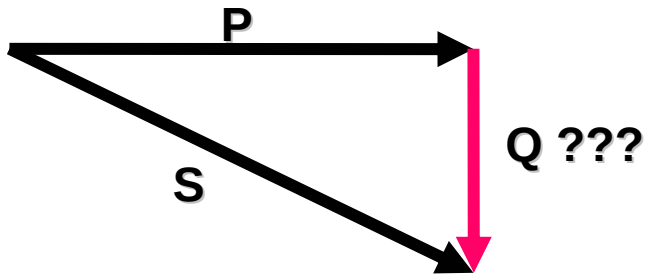


Wattmeter reading = 1.5 kW
Ammeter reading = 9.615 A rms

$Q_I = \sqrt{S^2 - P^2} = 1.754$ kVAR

$X = E^2/Q = 32.845$

$C = 1/2\pi f X_c = 80.761\mu F$



By calculating the current through the capacitor;
you will find that $Q_c = 1.737$ kVAR

Total kVAR = 1.754 kVAR – 1.737 kVAR = 16.51 VAR

$S_{new} = 1.50009$kVA

$$pf_{corrected} = \frac{1.5kW}{1.50009kVA} = 0.99994\text{☺}$$

Results

- The corrected power factor is 0.99994
- The new total current is (1.50009 kVA / 240 Volts), or **6.25** amps vs. **9.615** amps for poor power factor!
- This lower total current will translate to less heat losses in the circuit wiring, meaning greater system efficiency (less power wasted).

Easier Way to Find Capacitor Value

To properly select the amount of KVAR required to correct the lagging power factor of a 3-phase motor you must follow the steps as stated.

- **Step #1:** Determine KW and Existing Power Factor.
- **Step # 2:** Existing Power Factor on Table, move across table to Desired Power Factor. The number represented is your multiplier number.
- **Step #3:** Multiply KW by the multiplier of the Desired Power Factor.

Calculation Table for Capacitor Selection

Power factor Cos θ_1 before improvement	Power factor Cos θ_2 after improvement												
	1.0	**0.99**	**0.98**	**0.97**	**0.96**	**0.95**	**0.94**	**0.93**	**0.92**	**0.91**	**0.90**	**0.85**	**0.80**
0.5	1.73	1.59	1.53	1.48	1.44	1.40	1.37	1.34	1.30	1.28	1.25	1.11	0.98
0.52	1.64	1.50	1.44	1.39	1.35	1.32	1.28	1.25	1.22	1.19	1.16	1.02	0.89
0.55	1.52	1.38	1.32	1.27	1.23	1.19	1.16	1.12	1.09	1.06	1.04	0.90	0.77
0.57	1.44	1.30	1.24	1.19	1.15	1.11	1.08	1.05	1.01	0.99	0.96	0.82	0.69
0.6	1.33	1.19	1.13	1.08	1.04	1.01	0.97	0.94	0.91	0.88	0.85	0.71	0.58
0.62	1027	1.23	1.06	1.01	0.97	0.94	0.90	0.87	0.84	0.81	0.78	0.65	0.52
0.65	1.17	1.03	0.97	0.92	0.88	0.84	0.81	0.77	0.74	0.71	0.69	0.55	0.42
0.67	1.11	0.97	0.91	0.86	0.82	0.78	0.75	0.71	0.68	0.65	0.62	0.49	0.36
0.7	1.02	0.88	0.81	0.77	0.73	0.69	0.66	0.62	0.59	0.56	0.54	0.40	0.27
0.72	0.96	0.82	0.75	0.71	0.67	0.63	0.60	0.57	0.53	0.51	0.48	0.34	0.21
0.75	0.88	0.74	0.67	0.63	0.58	0.55	0.52	0.49	0.45	0.43	0.40	0.26	0.13
0.77	0.83	0.69	0.62	0.58	0.54	0.50	0.47	0.43	0.40	0.37	0.35	0.21	0.08
0.8	0.75	0.61	0.54	0.50	0.46	0.42	0.39	0.35	0.32	0.29	0.27	0.13	
0.82	0.70	0.56	0.49	0.45	0.41	0.37	0.34	0.30	0.27	0.24	0.21	0.08	
0.85	0.62	0.48	0.42	0.37	0.33	0.29	0.26	0.22	0.19	0.16	0.14		
0.87	0.57	0.42	0.36	0.32	0.28	0.24	0.20	0.17	0.14	0.11	0.08		
0.90	0.48	0.34	0.28	0.23	0.19	0.16	0.12	0.09	0.06	0.02			
0.91	0.45	0.31	0.25	0.21	0.16	0.13	0.09	0.06	0.02				
0.92	0.43	0.28	0.22	0.18	0.13	0.10	0.06	0.03					
0.93	0.40	0.25	0.19	0.15	0.10	0.07	0.03						
0.94	0.36	0.22	0.16	0.11	0.07	0.04							
0.95	0.33	0.18	0.12	0.08	0.04								
0.96	0.29	0.15	0.09	0.04									
0.97	0.25	0.11	0.05										
0.98	0.20	0.06											
0.99	0.14												

Notes

- For purely resistive circuits, pf is perfect “1”
- For purely inductive or capacitive circuits, pf is zero
- Poor pf can be corrected by adding a capacitor parallel to the circuit.
- The capacitor will have an opposite amount of the reactive power
- Too much capacitance will result in a low pf

Advantages of Good pf:

- For the same active power taken by the load, the line current drawn from the network reduces
  - The lower total current will translate to a less heat losses in the circuit wiring, meaning greater system efficiency (less power wasted); therefore reduced energy costs
  - Life time of these devices increase
  - Penalties for bad "pf" are canceled
  - Electrical bill is reduced

- The significant effect of improving the power factor of a circuit is to reduce the current flowing through that circuit which in turn result in the following benefit, Less total plant KVA for the same KW working power

POWER FACTOR	60%	70%	80%	90%	100%
REAL POWER (kW)	600	600	600	600	600
REACTIVE POWER (kVR)	800	612	450	291	0
TOTAL POWER (kVA)	1000	857	750	667	600

Power Factor Clause; DTE(D6.a)

- The rates and charges under this tariff are based on the customer maintaining a pf of not less than 85% lagging. Any pf less than 70% will not be permitted and the customer will be required to install at his own expense such as corrective equipment as may be necessary to improve pf. A penalty will be applied ….. Etc.
- DTE rates call for penalties ranging from 1 to 3% when power factor is between 85 and 70%.

Measurement of Power Factor And Latest Technology

- Fluke 43B(one phase)
- Fluke 434 Power Quality Analyzer(3 phase)
- Fluke 40

References

- http://quest.deco.com/emd/orgs/majorAccountServices/techpro/login.html
- http://memonline.com/pfc1.html
- S:\EP Common\ABB Inc\ABB.2004.LVNQ.Presentation

Any Questions ?
Thank you